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Dealing with sulfur deficiency in Iowa corn production

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Introduction

Research conducted for more than forty years (prior to approximately 2005) in Iowa rarely noted improved crop yield with sulfur (S) fertilization. Studies during that time period with corn and soybean found yield increase from S fertilizer application only three times out of approximately 200 trials. Research in the early 1980's also documented sufficient plant available S in the soil profile for crop production on most Iowa soil associations. Results of recent studies (2000-2005) in corn and soybean were consistent with the historical research. An example is research presented at this conference (Sawyer and Barker, 2002) where there was no corn or soybean yield increase from S application at six sites in Iowa across two years.

However, over the past decade alfalfa grown on some silt loam and loam soils in northeast Iowa exhibited a slowly worsening problem, with areas in fields of stunted growth and poor coloration. Investigations determined the growth issues were largely due to S deficiency, with the most prominent symptoms in field areas with low soil organic matter and side-slope landscape position. Results of S fertilization trials in Iowa with alfalfa, and suggestions for S management in alfalfa production, were discussed previously at this conference in a paper by Lang et al. (2006). Since then, on similar soils and on coarse textured soils, early corn growth has also exhibiting strong visual S deficiency symptoms.

The research reported here is from on-farm trials conducted to determine corn response to S fertilization in north-central to northeast Iowa. The following provides a summary of research, evaluation of methods to identify potential S deficiency, and S fertilization guidelines.

Corn response to sulfur fertilization

Three studies were conducted in north-central to northeast Iowa corn fields in 2006–2008 to evaluate S fertilization response in corn. The first study was designed to evaluate P and S containing fertilizer products. The second study was targeted to determine if S deficiency was responsible for visual plant yellowing (chlorosis) in early corn growth, and if so, the response to early sidedress applied S fertilizer. The third study evaluated corn response to S fertilization rate and through many sites the extent of S deficiency. All of these studies provide insight into the potential for corn response to S application and the magnitude of S deficiency in north-central to northeast Iowa corn production.

Sulfur fertilizer product evaluation

Two sites were chosen on producer fields in Allamakee and Winneshiek counties in 2006, a Seaton silt loam and a Renova loam soil. The previous year crops were soybean and long-term grazed grass pasture, respectively. Other than grazing in the grass pasture, neither site had a history of manure application. Tillage following soybean was shallow disking in the spring and no-till corn planted into the grass pasture. In 2008, a site was located in Cerro Gordo county on a Readlyn loam soil with no-tillage corn following soybean (several years of no-tillage). The fertilizer products evaluated were a Simplot and Mosaic 13-33-0-15S product (Simplot SEF in 2006 and Mosaic MES15 in 2008). The SEF and MES products contained half of the S as sulfate and half as elemental.

Fertilizer treatments were broadcast by hand prior to spring tillage or corn planting at the no-till sites. For this report, only treatments related to S response are discussed (S control, ammonium sulfate at 10 and 30 lb S/acre, and SEF and MES at 10 and 30 lb S/acre). Nitrogen and P rates were equalized. At the 2006 sites, the extractable soil sulfate-S concentrations were 6–8 ppm in the top 36 inches (8 ppm in the 0-6 inch depth). At the 2008 site, the extractable soil sulfate-S concentrations were 4–6 ppm in the top 36 inches (4 ppm in the 0-6 inch depth).

In 2006, the corn grain yield response across sites between the control and 10 lb S/acre as ammonium sulfate or SEF was 15 bu/acre (196 vs. 211 bu/acre). There was no yield increase to additional S application with the 30 lb S/acre rate for either S fertilizer. The ear leaf S concentration was increased from 0.15% S in the control to 0.18% and 0.21%, respectively, for the 10 and 30 lb S/acre rates. The leaf S concentration and corn grain yield was the same for both ammonium sulfate and SEF, indicating similar plant-available S supply from both fertilizer products.

In 2008, despite visual S deficiency symptoms when corn plants were small where no S was applied, there was no yield response to S application with either S product or rate of application (172 vs. 168 bu/acre, respectively, for the control and S application average). The ear leaf S concentration was also not influenced by S application from the ammonium sulfate or the low rate of MES, but was increased with the highest rate of MES (0.16% S in the control and 0.19% with MES).

Corn response to sulfur application with visual deficiency symptoms

In 2006, six sites were selected in northeast Iowa based on expectation of S deficiency, either through visual observation of early plant S deficiency symptoms being present or previous experience indicating that soil conditions and previous crop would be conducive to S deficiency. Therefore, sites were considered specifically “chosen”, and not a set of sites with random potential of response to S application. Sites did not have recent or known manure application history.

Calcium sulfate was surface broadcast applied sidedress after early corn growth at 40 lb S/acre, with a control treatment for comparison. A non-limiting S rate was chosen to allow measurement of S response, with expectation the 40 lb S/acre rate would maximize any potential yield increase.

Corn yield was increased with the sidedress calcium sulfate application at five of six sites (Table 1). The yield increases were quite large, especially considering the surface sidedress fertilizer application. However, the sites were chosen based on expected S deficiency, with many sites showing severe plant yellowing. Therefore, substantial yield increase might be expected. With rainfall after application, plant response (increase in greenness) was observed in a short time period. This would also indicate an expected plant growth and yield increase. The site with no response to S application (and high yield with no applied S) did have the highest extractable soil sulfate-S concentration.

Table 1. Effect of S fertilizer application on corn grain yield, 2006.

| County | Previous crop [†] | Soil type [‡] | Soil SO ₄ -S [§] | Grain yield | |
|--------------|----------------------------|------------------------|--------------------------------------|-----------------|-------------------|
| | | | | - S | + S [¶] |
| | | | ppm | --- bu/acre --- | |
| Buchanan | Sb | Sparta lfs | 6 | 123 | 151* |
| Buchanan | Sb | Sparta lfs | 7 | 154 | 198* |
| Delaware | Sb | Chelsa lfs | 9 | 88 | 108* |
| Delaware | Sb | Kenyon l | 13 | 196 | 204 ^{NS} |
| Allamakee | A | Fayette sil | 3 | 96 | 172* |
| Allamakee | A | Fayette sil | -- | 118 | 171* |
| Across Sites | | | | 129 | 167* |

[†] Sb, soybean; A, first-cut alfalfa harvested.

[‡] lfs, loamy fine sand; l, loam; sil, silt loam.

[§] Extractable sulfate-S in the 0-6 inch soil depth.

[¶] Sulfur applied at 40 lb S/acre. Symbol indicates statistically significant (*) or non-significant (^{NS}) yield increase with S application, $p \leq 0.10$.

Across all sites, the yield increase from S application was 38 bu/acre. This yield increase would easily cover the required S fertilization cost. Since only one non-limiting S rate was applied, it is not possible to determine an economic application rate. These results indicate that a substantial corn yield increase to S application is possible when soil conditions are conducive to low S supply and severe S deficiency exists. In this study, those conditions were coarse textured soils and a soil/landscape position similar to that with documented S deficiency in alfalfa.

Corn response to sulfur fertilization rate

An expanded study was conducted in 2007 and 2008 at 45 sites in north-central to northeast Iowa to determine corn response to S rate. Counties with sites in 2007 were (number): Allamakee (3), Black Hawk (1), Buchanan (4), Clayton (4), Delaware (6), Fayette (1), Winneshiek (1). Counties with sites in 2008 were: Black Hawk (3), Buchanan (1), Butler (4), Chickasaw (2), Floyd (3), Hancock (1), Howard (3), Story (1), Worth (4), Winneshiek (3). The sites were selected to represent major soils, cropping systems, and a range in potential S response. Most sites were on producer fields. Sites had no recent or known manure application history. Calcium sulfate was surface broadcast applied with no incorporation shortly after planting at 0, 10, 20, and 40 lb S/acre. Individual site S response was determined by contrast comparison of the no S control application vs. applied S. Means and statistical analyses were computed across all sites and by fine and coarse soil textural grouping. Quadratic-plateau regression models were fit to the grain yield response for the fine- and coarse-textured responsive site groupings. Economic optimum S rate was determined with S fertilizer at \$0.50/lb S and corn grain at \$4.00/bu.

Corn grain yield was increased with S fertilizer application at 17 of 20 sites in 2007 and 11 of 25 sites in 2008 (Figures 1 and 2), and ear leaf S concentration was increased at 16 sites each year (data not shown). Across all sites, the average yield increase was 13 bu/acre. When grouped by soil texture for responsive sites, the yield increase was 15 bu/acre for the fine-textured soils (loam, silt loam, silty clay loam, and clay loam) and 28 bu/acre for the coarse-textured soils (fine sandy loam, loamy fine sand, and sandy loam). Grain yields increased with S application at 21 of 34 (62%) fine-textured soil sites and 7 of 11 (64%) coarse-textured soil sites. These are frequent and large yield increases to S fertilization. However, sites located more toward the north-central and central geographic areas of Iowa had a lower frequency of yield response to S application, indicating soil or other factors affecting potential need for S fertilization that are different from the northeast area of Iowa.

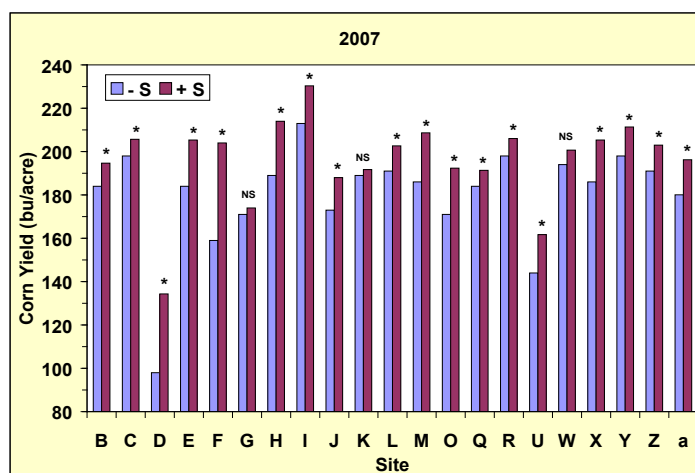


Figure 1. Corn grain yield response to S application (no S vs. plus S), 2007. The average across all sites is designated by (a), (*) indicates statistically significant response to S, and (NS) indicates non-significant response to S ($p \leq 0.10$).

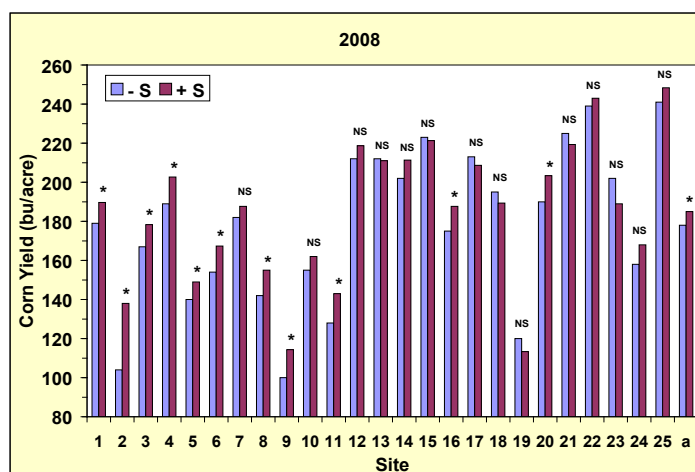


Figure 2. Corn grain yield response to S application (no S vs. plus S), 2008. The average across all sites is designated by (a), (*) indicates statistically significant response to S, and (NS) indicates non-significant response to S ($p \leq 0.10$).

An important question is what is the economic optimum S rate? When analyzed for the responsive sites, the maximum response rate for the 21 fine-textured soil sites was 17 lb S/acre, with an economic optimum rate at 16 lb S/acre (Figure 3). For the 7 coarse-textured soil sites, the maximum response rate was 25 lb S/acre, with an economic optimum rate at 23 lb S/acre (Figure 3). The economic optimum S rate is near the maximum response because the fertilizer cost (rate times price) is low compared to the yield return (yield increase times corn price).

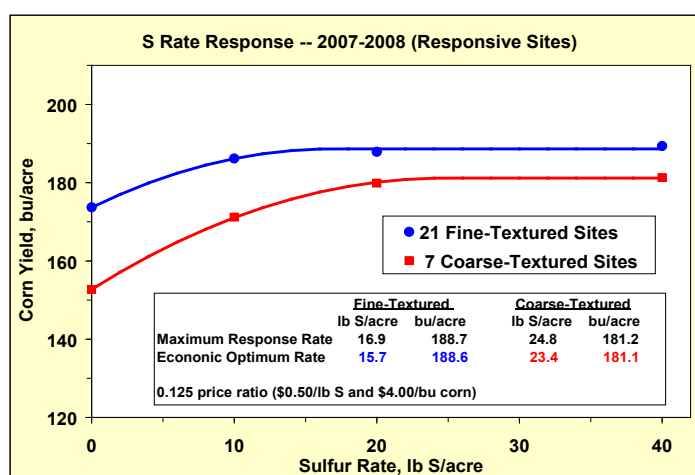


Figure 3. Corn grain yield response to S application rate at responsive sites, 2007-2008.

One test for evaluating potential S deficiency is plant analysis for ear leaf S concentration. Figure 4 shows this relationship for yield response to 40 lb S/acre application. There is a wide range in published minimum sufficiency concentrations for corn ear leaves at tassel/silking, 0.10 to 0.21% S (Jones et al., 1990; Dick et al., 2008). The current study does not confirm or refute these minimum levels. Across measured leaf S concentrations there was no clear relationship between ear leaf S and yield response. Therefore, it is not possible to define a critical level from this study. Sulfur application increased leaf S concentration, but was not a large increase (across sites, an increase of 0.02% S with the 40 lb S/acre rate). With the 40 lb S/acre rate, the leaf S concentration was below 0.21% S at all but one site (data not shown).

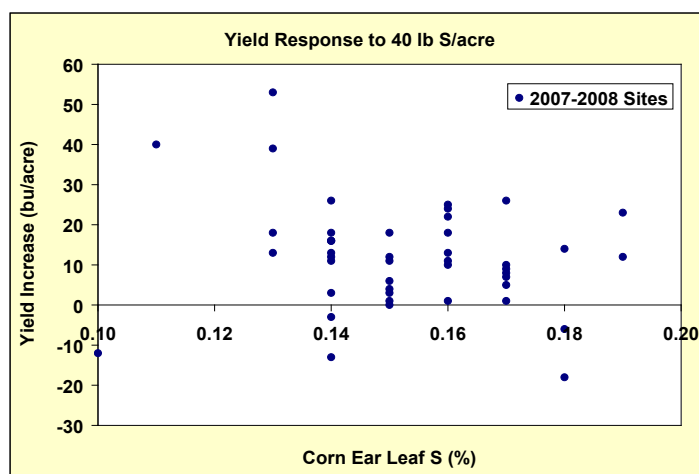


Figure 4. Corn grain yield response to S application as related to ear leaf S concentration in the no-S control, 2007-2008.

Another test for evaluating potential S deficiency is soil testing for extractable sulfate-S. Concentrations (0-6 inch depth) were not related to yield response (Figure 5). Also, several sites had concentrations above the 10 ppm S level considered sufficient (Hoelt et al., 1973), but responded to S application. This has been found in other studies where the sulfate-S soil test has not been reliable for predicting crop response to S application on soils in the Midwest USA (Hoelt et al., 1985; Sawyer and Barker, 2002). Supply of crop-available S is related to more than the sulfate-S concentration in the top six inches of soil, thus the poor relationship between relative yield and soil test. Soil organic matter has a somewhat better relationship to yield response, but for similar reasons does not clearly differentiate between responsive and non-responsive sites (Figure 6). Yield response tended to be low with high soil organic matter, but there is considerable variation in response across organic matter levels. These results highlight the complex combination of environmental, soil, and crop factors that result in deficient or adequate supply of available S.

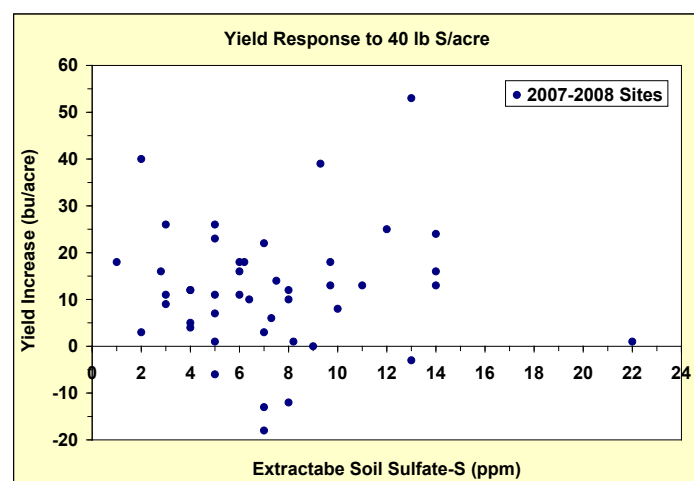


Figure 5. Corn grain yield response to S application as related to extractable soil sulfate-S concentration (0-6 inch soil depth) in the no-S control, 2007-2008.

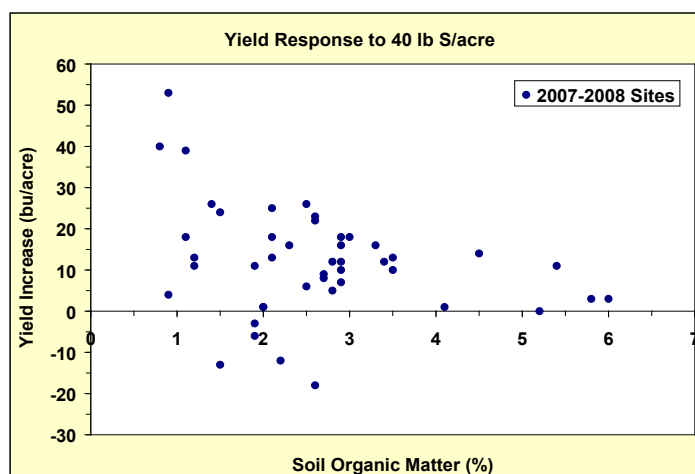


Figure 6. Corn grain yield response to S application as related to soil organic matter level (0-6 inch soil depth) in the no-S control, 2007-2008.

Summary

Corn grain yield increase to S fertilization occurred with high frequency. Also, the magnitude of yield increase was large. Across the two years of rate studies, 62% of the sites had a statistically significant yield increase to applied S fertilizer, with similar frequency for fine- and coarse-textured soils. For the responsive sites, the yield increase was 15 bu/acre for fine-textured soils and 28 bu/acre for coarse-textured soils. Analyzed across S rate for responsive sites, the economic optimum S rate was 16 lb S/acre for fine-textured soils and 23 lb S/acre for coarse-textured soils.

A wide range of soils have been studied. A notable trend was that 6 of 7 sites with silty clay loam or clay loam soil texture did not have a corn yield response to S application. For all studies, the 47 sites with loam, silt loam, fine sandy loam, loamy fine sand, and sandy loam soils had a frequency of S response that was large at 72%, but not all of those sites (13) had a yield increase with S application.

This research indicates a change in need for S fertilization, especially in northeast Iowa and the associated soils, and that S application is an economically viable fertilization practice on many soils. However, the research also shows that corn does not respond to S application in all fields or field areas and that chance of S response decreases outside of the northeast Iowa geographic area and on soils with greater relative clay content. In addition, more research is needed to study S response in corn and other row crops across a larger geographic area of Iowa, extending into central, north-central and east-central Iowa, and the associated soils in those regions. Also, additional evaluations are needed to develop tools for better predictive indices of S deficiency and need for S fertilization. These tools would provide better decision making and enhance positive economic return to S fertilization for producers.

Suggestions for managing sulfur applications in corn production

- The extractable sulfate-S concentration in the 0-6 inch soil depth is not reliable for indicating potential S deficiency or need for S application.
- The S concentration in ear leaves collected at silking can indicate low S supply, but a specific critical concentration with modern hybrids has not been established in this research.
- For confirmed S deficiencies, on fine-textured soils apply approximately 15 lb S/acre and on coarse-textured soils apply 25 lb S/acre.
- Manure is a good source of S and eliminates the need for S fertilizer application.

- Sulfur deficiencies have been documented and large crop yield response measured in some fields. However, at this time we are uncertain about the geographic extent of S deficient soils, especially in areas nearby northeast Iowa. Some common soil conditions where S deficiency has been found include low organic matter soils, side-slope landscape position, eroded soils, and coarse-textured soils. Sulfur deficiency symptoms and yield responses have been noted in reduced- and no-till systems with fine-textured soils in nearby areas of Iowa and other states. Lack of soil mixing and cooler soils reduce mineralization which slows release of S from organic materials, a main source of S.
- Research to date has also not fully documented the variability of deficiency within fields. Work with alfalfa clearly showed differential response in poor and good coloration/growth areas, indicating that whole fields would not respond to S application. However, it is likely most prudent to simply fertilize entire fields when deficiency exists rather than attempt site-specific applications because of the relatively low cost of S fertilization, many fields indicating considerable area with S deficiency, large yield increases with S application, and need to plant sample for determining S deficiency. Site-specific response is possible, but inexpensive and reliable methods are needed to “map” S deficiency. This is especially problematic in corn as visual symptoms are not always present or obvious, especially with minor S deficiency and small but economic yield response. Research and development is needed to provide tools for reliable S deficiency detection.

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